Evapotranspiration in boreal forest catchments: upscaling by process models and open GIS data

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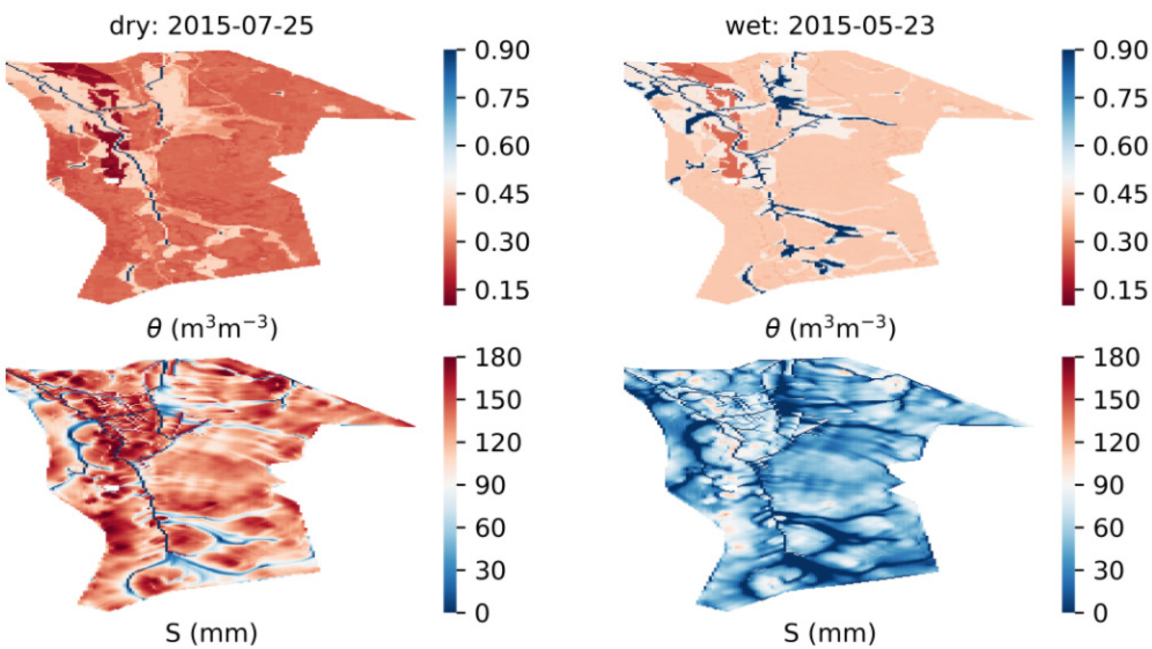

Background

- Boreal mixed coniferous forests cover ~80% of land area in Finland
- Forest management creates mosaic landscape
- Why actual ET and its spatial variability?
  - Soil moisture & biogeochemical cycles, growth and climate feedback
  - Improved description of ET will reduce uncertainties in catchment models

Objectives:

1) Develop generic daily stand-level ET model
   - validate against eddy-covariance data
2) Upscale to landscape scale using open data
   - evaluate using annual ET from catchment water balance

”Simple, applicable at large scale, minimal calibration”

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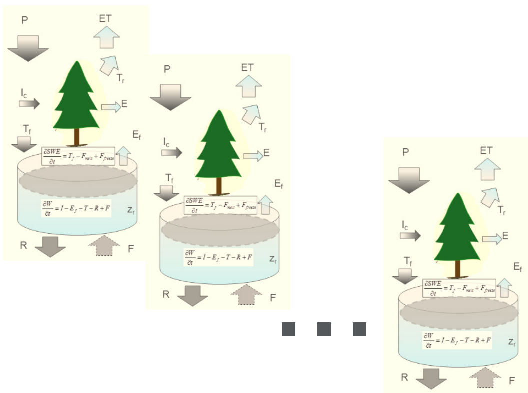
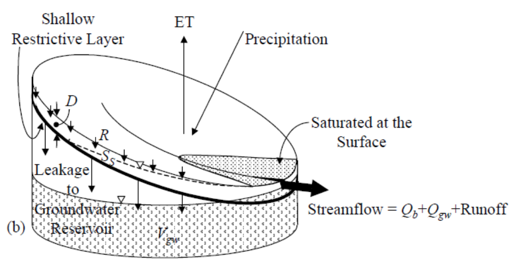
Semi-distributed catchment model

Catchment → (n x m) grid of buckets





+ TOPMODEL for streamflow generation & returnflow

Launiainen et al. 2018, in prep.

INPUT 2D-GRIDS:

- Conifer & deciduous LAI, tree height
- Soil map, root zone organic layer depths
- Catchment boundaries
- Topografic wetness index TWI

DAILY FORCING

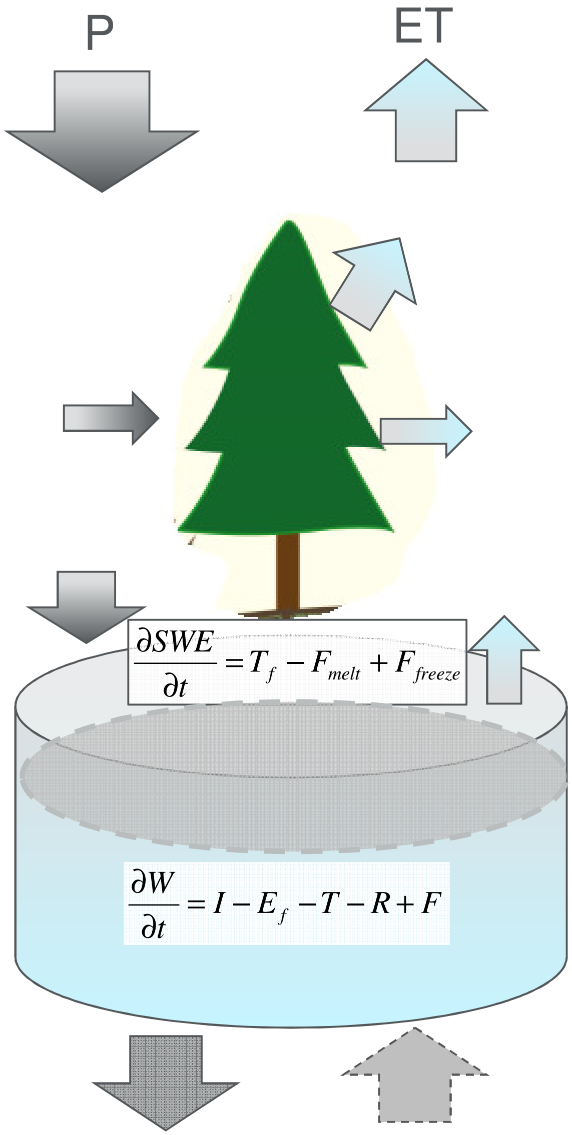
- Precip, SW radiation, temperature, RH (or VPD), wind speed

DAILY GRID-OUTPUTS:

- ET & components
- Snow water equivalent
- Organic layer & root zone moisture
- Drainage from root zone
- Saturation deficit (→ proxy of water table)
- Returnflow & dynamics of saturated area

CATCHMENT OUTLET

- Streamflow



Three-source Penman-Monteith

- Evaporation (sublimation) of canopy intercepted rain (snow)
- Canopy transpiration
- Evaporation from ground

$$\boxed{E_i = \frac{1}{L_v}\frac{\Delta(R_{n,i}) + \rho_a c_p G_{a,i} D}{\Delta + \gamma(1 + G_{a,i}/G_i)}}$$

Temperature-index snow model

Two-layer bucket model

- Organic layer
- Root zone

Leaf to canopy stomatal conductance

$$\boxed{g_s = g_o + 1.6\left(1 + \frac{g_1}{\sqrt{D}}\right)\frac{A}{C_a}}$$

Medlyn et al. 2011
'USO'

scale-analysis & hyperbolic light-response

$$g_s \sim \frac{1.6\,(1+g_1)}{C_a}\,\frac{A_{max}\,PAR}{PAR+b}\,\frac{1}{\sqrt{D}}$$

g_{sref}

Exponential PAR within canopy

$$PAR(L) = PAR_o\,exp(-k_p\,L)$$

- A net photosynthesis
- g_1 depends on water use strategy
- g_{sref} light-saturated stomatal conductance at D = 1 kPa & const C_a

- Scots pine: g_{sref} ~2.5 mm/s (2.2 – 2.8), b ~30 – 50 Wm^{-2}
- Birch, aspen ~4.0 – 4.5 mm/s
- k_p ~0.6

$$\boxed{G_c = \frac{g_{sref}}{k_p}\,ln\left(\frac{PAR+b}{PAR \times exp(-k_p LAI) + b/k_p}\right) \times \frac{1}{\sqrt{D}} \times f(\theta_{REW}) \times f_{CO2} \times f_S.}$$

plant traits

Leaf → canopy

soil moisture

atm. CO2

phenology

Medlyn et al, 2011.
Global Change Biol. 17, 2134-2144

https://github.com/LukeEcomod/EGU2018

Parameterization

- Mainly from literature
- Some parameters calibrated
  - a single flux site, Hyytiälä, Southern Finland
- 1 for ground evaporation:
  - multi-layer SVAT –model APES
  - sub-canopy EC data
- 1 for transpiration
  - g_{sref} from leaf gas exchange
  - check against EC data
- 1 for interception of rainfall:
  - capacity = w x LAI, using throughfall data

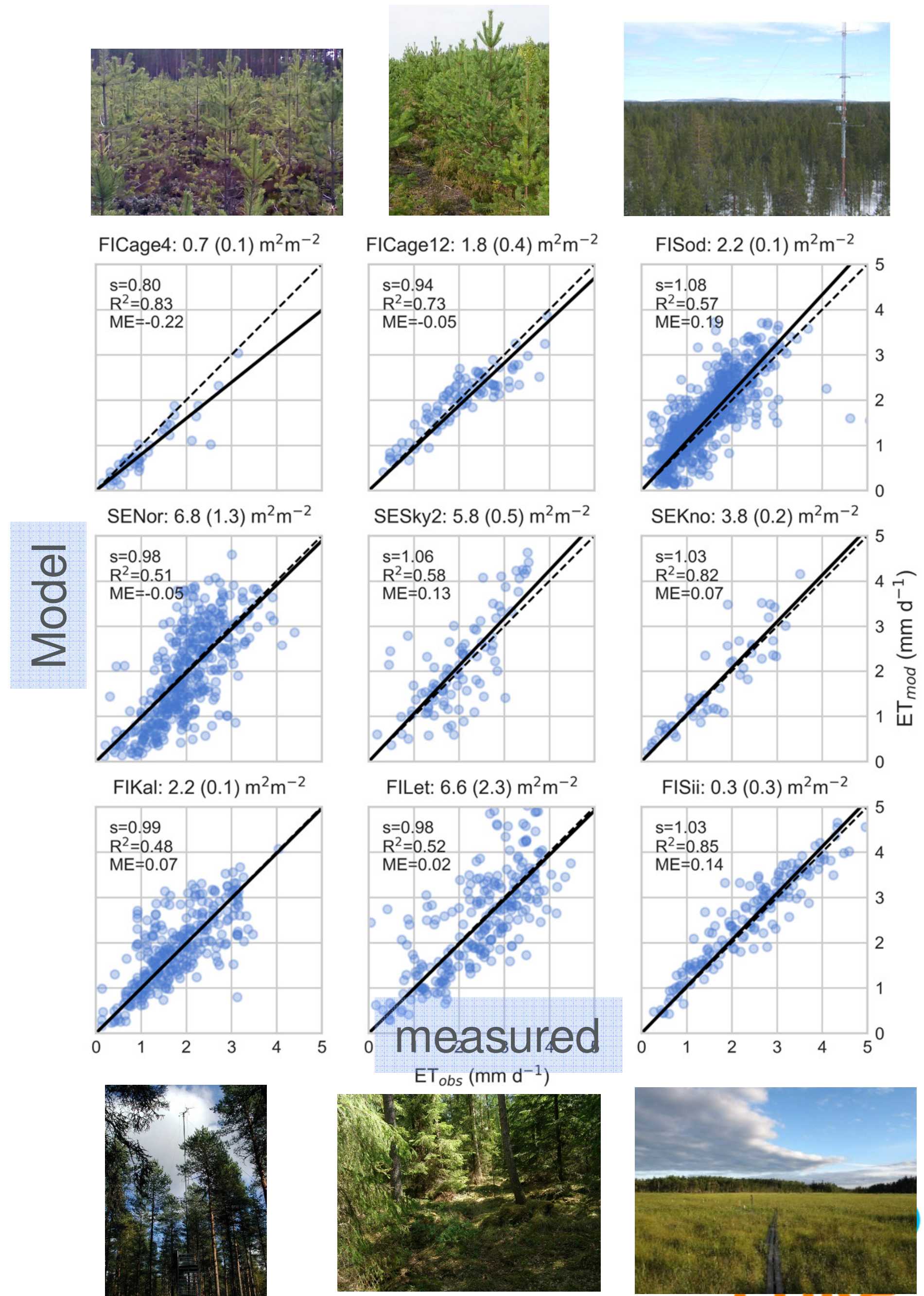
APES: Launiainen et al. 2015 Ecol. Mod

Site scale validation

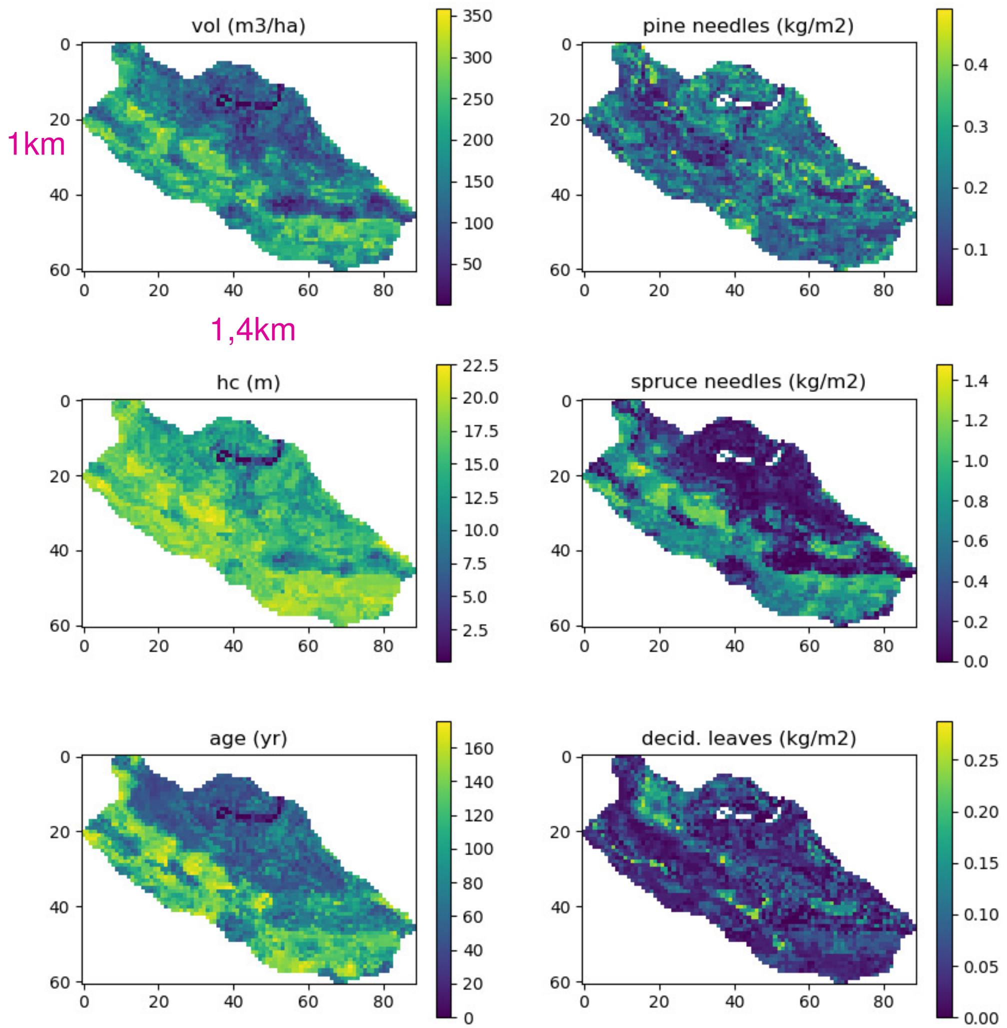
- 9 EC sites from Finland & Sweden, 60 N to 68 N
- LAI (1-sided) from 0.2 to 6.8 m^2m^{-2}
- Pristine peatland … dense managed forests

- Daily ET
  - dry-canopy conditions
  - Growing season (May-Oct)

- Independent comparison



Multi-source National Forest Inventory (16 X 16 m)



- 45 raster themes (geotiff)
- Open data, 3 year update interval
- > 80 0000 forest inventory plots
- Landsat + DEM, topographic basemap
- kNN –interpolation

- LAI = M x SLA

Comparison with MODIS LAI: Härkönen et al 2015 Bor. Env. Res. 20: 181–195

http://kartta.luke.fi/index-en.html

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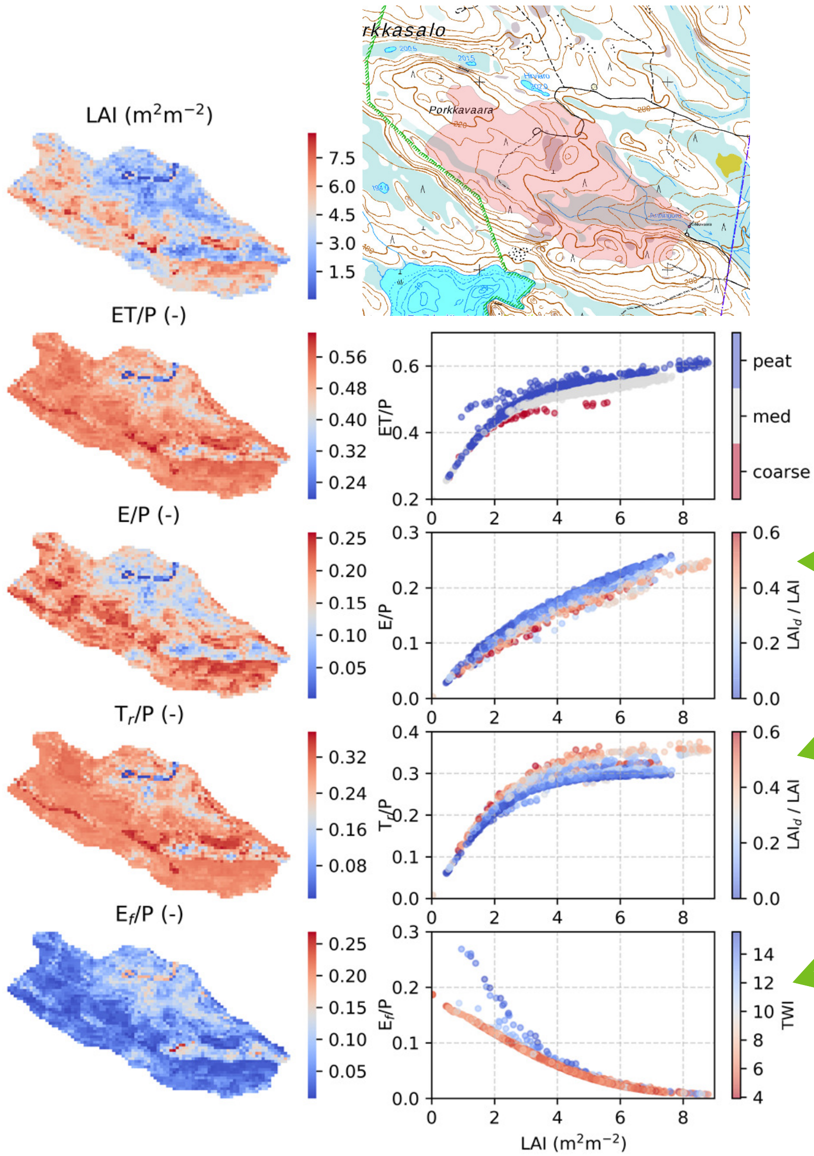
Spatial variability within catchment



Porkkavaara catchment, Eastern Finland, 64ha, 16x16m grid

ET / P

- LAI –relationship non-linear; inflection point at LAI 2 to 3 m^2m^{-2}

Interception

- Capacity ~ a x LAI
- Snow interception

Transpiration

- Saturates due to light limitations
- Higher where deciduous dominant
- Drought stress at coarse soils

Evaporation from ground

- available energy
- Gridcells with high TWI receive returnflow & behave as wet surfaces

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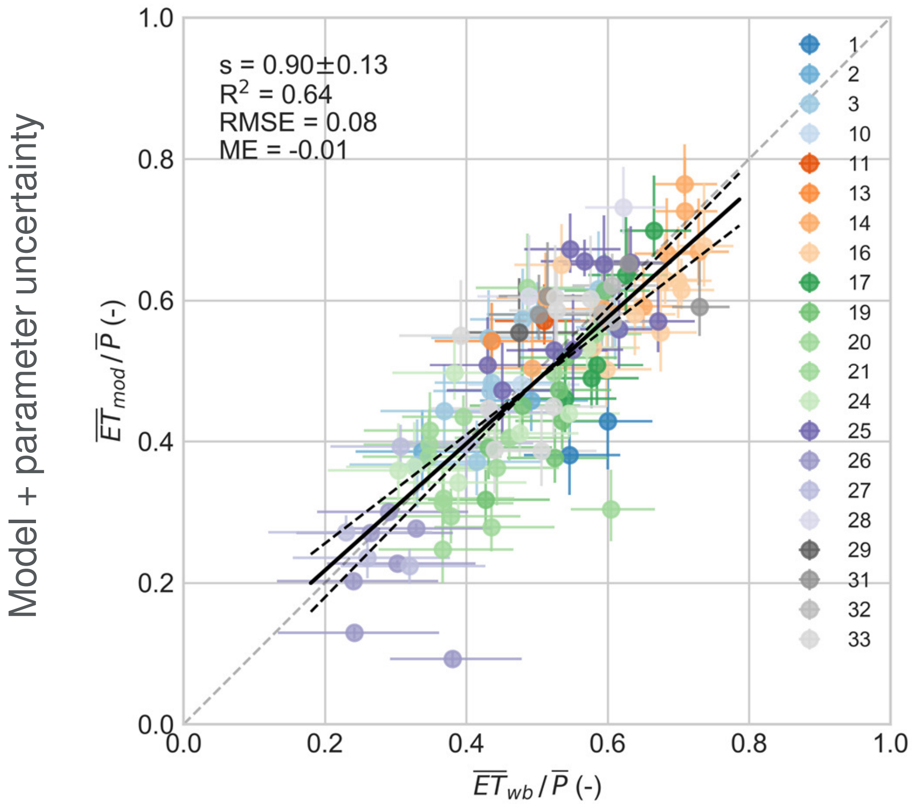
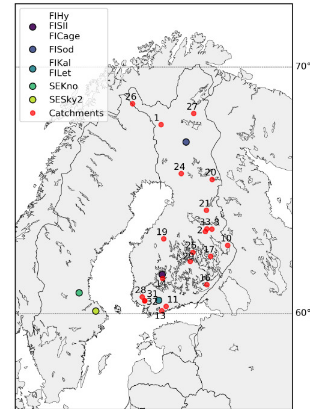
Annual evaporation ratio ET/P



Catchment water balance ET = P – Q



- 21 headwater catchments over Finland. Streamflow data 1 - 10 yr / catchment
- Independent comparison

- Across-catchment variability primarily due to north-south gradient:
  - E_{pot} / P
  - Length of snow-cover & annual snowfall
  - LAI

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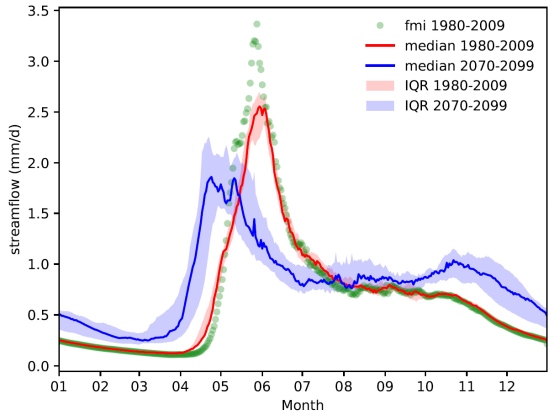
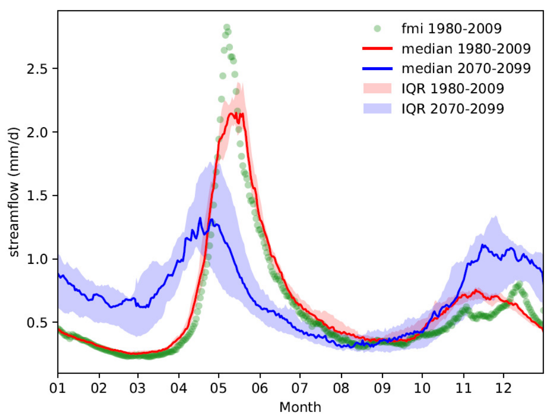
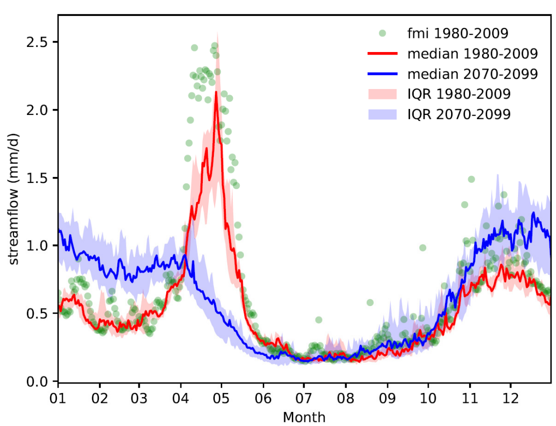
Climate projections



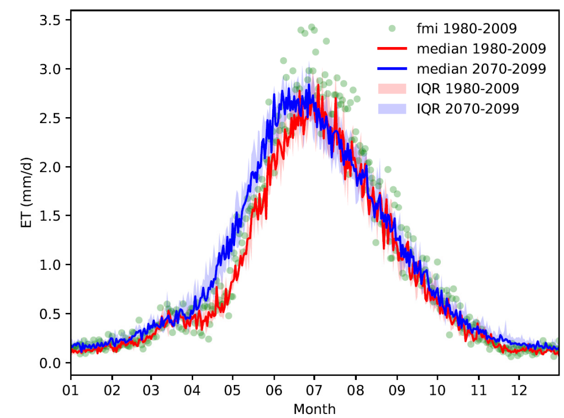
Lompolojänganoja, Muonio



Porkkavaara, Sotkamo



Paunulanpuro, Orivesi



- Larger evaporative demand
- Increasing ground evaporation
- Higher wintertime interception
- Transpiration:
    - Increases in spring & early summer
    - Drought-induced decrease in July-August

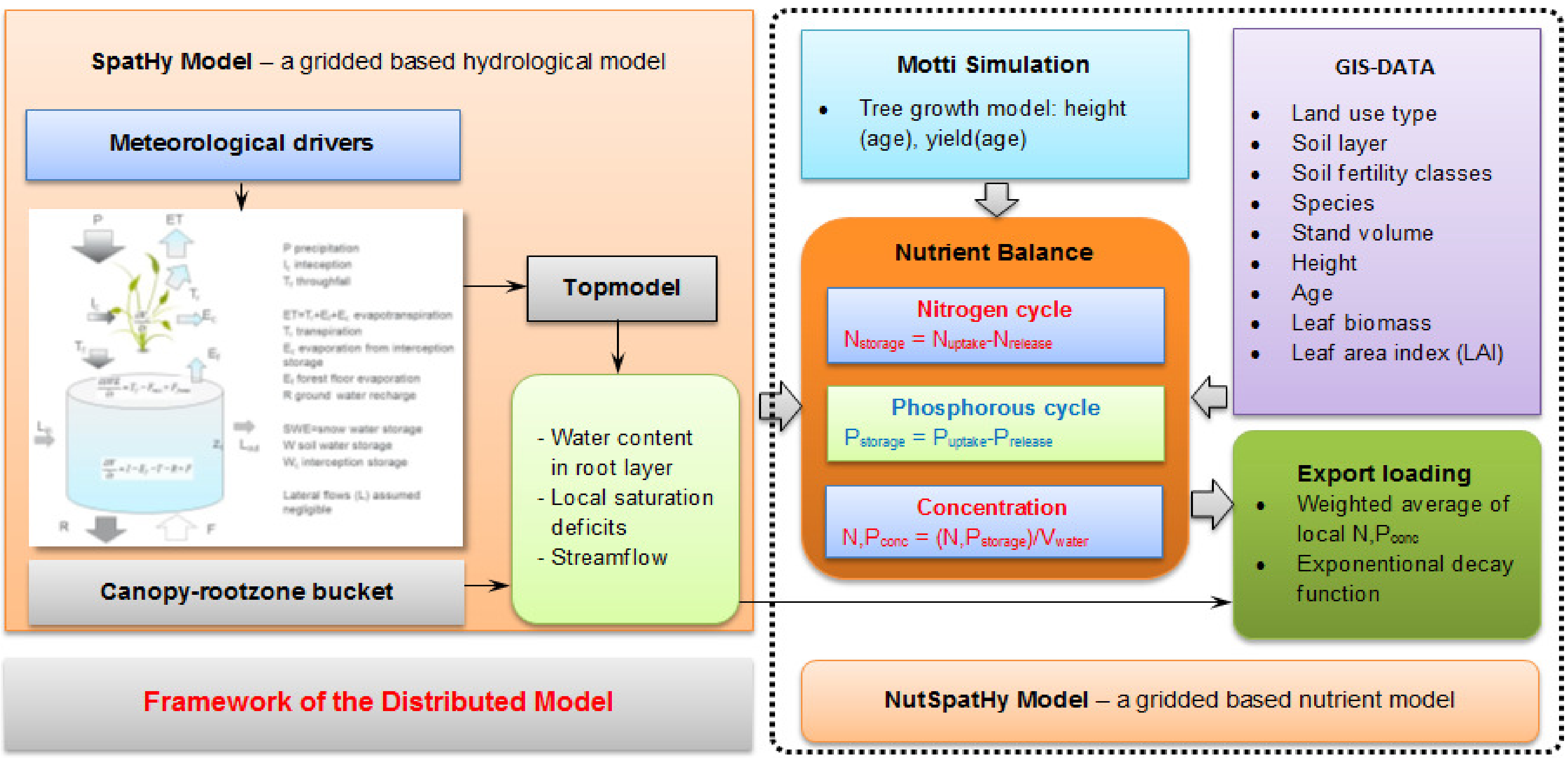
https://github.com/LukeEcomod/EGU2018

NutSpatHy

- **A grid-based distributed nutrient model for predicting nitrogen (N phosphorous (P) leaching in forested catchments**
- **Model key features:**
  - Grid-based nutrient balance (Δstorage = release - uptake)
  - Nutrient concentration prediction (conc = storage/water_volume)
  - Export loading simulation based on SpatHy runoff prediction
  - Spatiotemporal modelling of nutrient dynamics


Mingfu Guan


Ari Lauren



FRESHHABIT (2016-2022, EU LIFE+)

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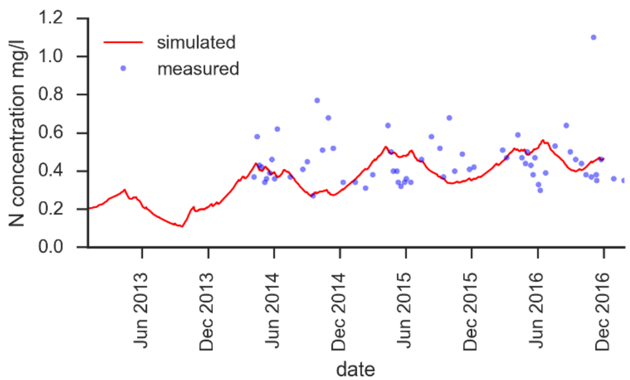
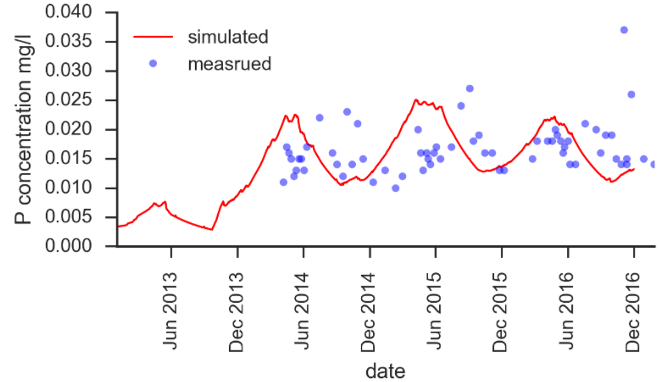
- **N and P concentration**

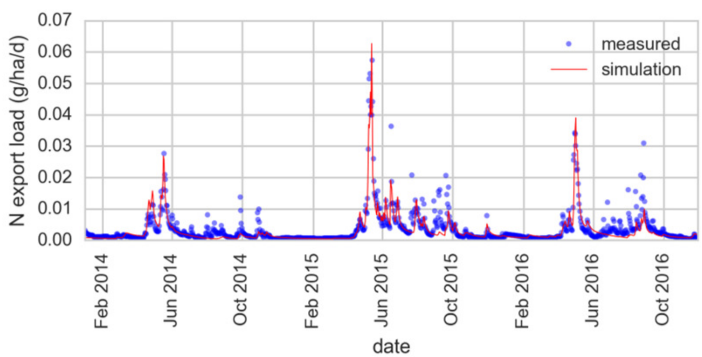
Nutrient concentration is reasonably predicted considering the complex chemical process and a series of uncertainties of parameters and input data.

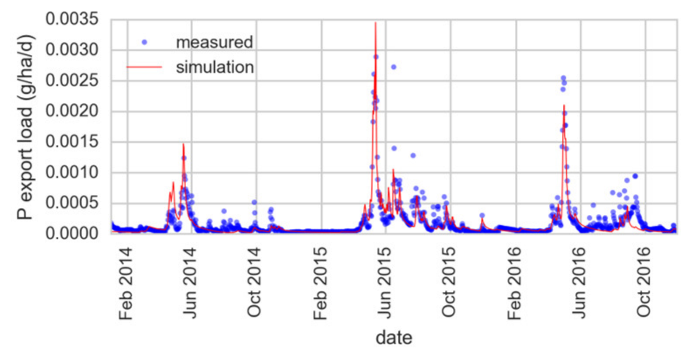




- **Daily and monthly N and P export loading**

Good performance in the prediction of export loading verifies the controlling role of hydrology on nutrient transport processes.

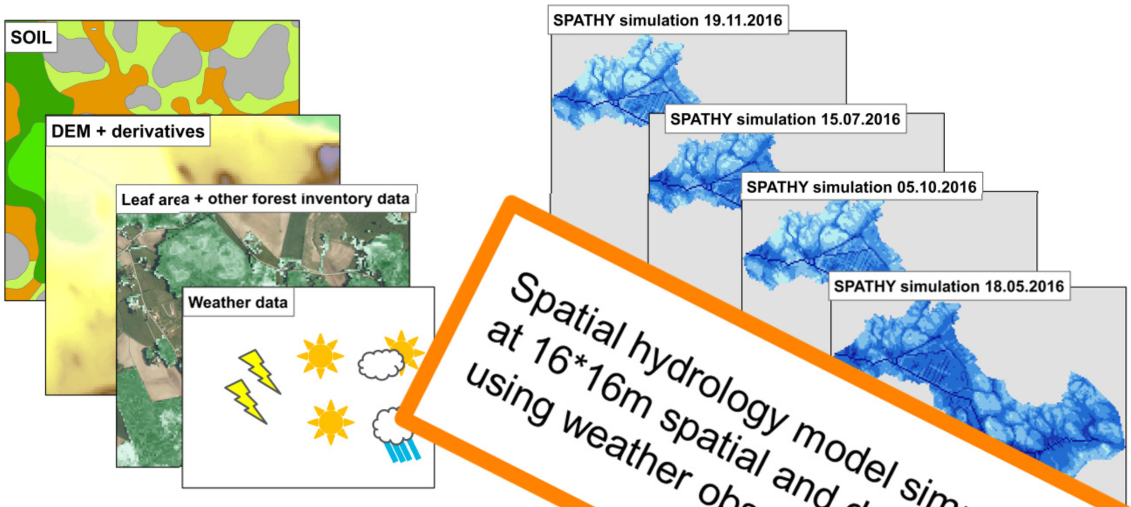




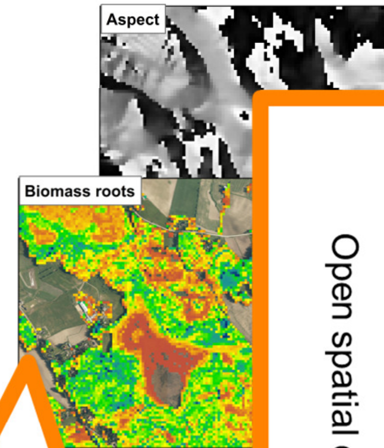
Daily N and P export loading: NSC = 0.76, correlation coef.= 0.81

Dynamic forest trafficability prediction by fusion of open data, hydrologic forecasts and harvester-measured data

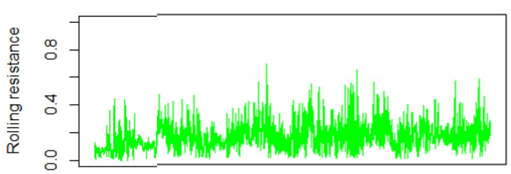
Aura Salmivaara



Spatial hydrology model simulations at 16*16m spatial and daily temporal resolution using weather observations and forecasts



Open spatial data



Forest machine measured data for improving prediction models

Rut depth prediction f(t, x, y)

Salmivaara, A., Launiainen, S., Ala-Ilomäki, J., Kulju, S., Laurén, A., Sirén, M., Tuominen, S., Finér, L., Uusitalo, J., Nevalainen, P., Pahikkala, T., and Heikkonen, J. 2017. *Dynamic forest trafficability prediction by fusion of open data, hydrologic forecasts and harvester-measured data. Poster.*

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Take home!

- Daily forest ET can be predicted with simple scheme with no site / catchment-specific calibration
- A three-source model seems as a good compromise

- Lot of things going on:
  - Forest trafficability
  - Towards spatial biogeochemistry
  - Radiation heterogeneity by topography & surrounding canopies

- What can be done at one point should be done spatially

- Codes (Python 2.7/3.x)

https://github.com/LukeEcomod/EGU2018

Thank you!

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Presentation available at:
https://github.com/LukeEcomod/EGU2018

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